Multi-Purpose Acoustic Imaging System for Shallow Water AUV Operations

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Contract Number N0001400C0484

LONG TERM GOALS

As the maritime threat has shifted from the deep oceans to the littoral, the need for improved shallow water survey and imaging capabilities has increased. Among the many challenges is the need to develop sensors that can be deployed on Autonomous Underwater Vehicles (AUV's) to support covert shallow water and surf zone mine detection and clearance operations. In particular, the integration of a high performance, forward looking, low power sonar on these vehicles would nearly double their operational effectiveness, thereby improving the timeliness and efficiency of the survey methods currently employed.

OBJECTIVES

The Phase II program objectives are to refine, scale-up, and implement technology demonstrated in the Phase I SBIR (contract N00014-99-M-0200) to develop an advanced imaging system using piezocomposite transducer technology for integration with AUV's. This includes refinements to the Phase I array design, increased receive array element count, integrated electronics, improved hydrodynamics of the nose-cone, and the demonstration of composite injection molding for low cost array fabrication.

APPROACH

The Phase II program is separated into three tasks and will result in the development of technology and tooling to mass produce low cost curved linear arrays for improved forward looking imagery on AUV's. Task 1 involves designing and fabricating an improved version of the Phase 1 array to support future battle field exercises and demonstrations. In Task 2, a sonar array system with a higher element count and embedded pre-amplifiers will be designed and fabricated using injection molded composite. Vehicle hydrodynamics will be improved by incorporating the new array into a modified parabolic nose cone. Task 3 consists of designing, building, and testing the tooling for injection molding of composite which meets the requirements determined in Tasks 1 and 2.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2001**	2. REPORT TYPE	3. DATES COVERED **00-00-2001 to 00-00-2001**

4. TITLE AND SUBTITLE **Multi-Purpose Acoustic Imaging System for Shallow Water AUV Operations**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Materials Systems Inc.,,543 Great Road,,Littleton,,MA, 01860**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
As the maritime threat has shifted from the deep oceans to the littoral, the need for improved shallow water survey and imaging capabilities has increased. Among the many challenges is the need to develop sensors that can be deployed on Autonomous Underwater Vehicles (AUV's) to support covert shallow water and surf zone mine detection and clearance operations. In particular, the integration of a high performance, forward looking, low power sonar on these vehicles would nearly double their operational effectiveness, thereby improving the timeliness and efficiency of the survey methods currently employed.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**7**	

WORK COMPLETED

Task 1: Improvements to Phase I Sonar Array

Results of performance testing of the Phase I array were favorable. Florida Atlantic University (FAU) requested several major modifications to the mounting hardware configuration to allow it to be deployed on their larger diameter vehicle as well as the 254 mm diameter “Morpheus” vehicle. These changes required a different radius of curvature for the array and modifications to the hemispherical nosecone encapsulation mold to allow flush mounting, which will improve vehicle hydrodynamics. Additionally, a camera is to be installed inside the nosecone for obtaining visual records to compare with the generated sonar images. New curving and assembly fixtures were fabricated for the changed radius of curvature of the array. Modifications were made to the nosecone encapsulation mold and the back plate to incorporate mounting provisions for the camera.

The projector and receiver assemblies have been completed and are awaiting final connections before encapsulation into the nosecone. The completed assembly will be shipped to FAU for integration with their electronics and installation on a test vehicle when one becomes available.

Task 2: Second Generation Sonar Array

The concept for the second generation array has been finalized. The receive array will have 192 elements and be 159 mm [6.25 in.] in diameter. The projector will consist of a single element curved to the same diameter as the receiver. Upon completion of the injection molding tooling under development in Task 3, work will begin on fabrication of the second generation array.

At a review meeting held in Panama City on February 21, 2001, concern was raised about beam distortion due to non-uniform thickness of the encapsulation material in a parabolic nosecone. MSI conducted a 2D finite element study and quantified these lensing effects by modeling a semi-circular array encapsulated in a parabolic nosecone using PZ-FLEX, a finite element modeling code.

Task 3: Manufacturing Scale Up

The new injection molding tooling design and fabrication has been completed. Initial runs of small quantities have produced good parts which are now undergoing dimensional and electrical analysis. The molded parts were poled, cast with polymer matrix, and ground to three different thicknesses to determine minimum, normal operational, and maximum frequency ranges for the composite. The impedance curves are clean, indicating very positive results from the new tooling.

RESULTS

A new matching layer bonding fixture was designed and fabricated which will improve the element to element uniformity. This will result in reduced system calibration time and better imaging.

Results of the PZ-FLEX modeling indicated that a solid urethane nosecone would bend the main response axis (MRA) of the beam by up to 3º, depending on the steering angle. However, a free-flooding nosecone with only a 6.35 mm [0.25 in.] urethane paraboloid shell did not produce appreciable bending of the MRA at any steering angle. Tables 1 and 2 summarize the results of the study.

Steering Angle

	08	158	308	458	608
MRA	0	2	3	3	2
-3 dB width	4.28	4.0 8	4.08	4.08	4.08

Table 1. Main Response Axis (MRA) calculations showing up to 3° of bending in a Solid Urethane Encapsulation

Steering Angle

	08	158	308	458	608
MRA	0	0	0	0	0
-3 dB width	4.28	4.28	4.28	4.28	4.28

Table 2. Main Response Axis (MRA) calculations showing no bending in a Water Filled Urethane Shell Encapsulation

Figure 1 is a photograph of a piezocomposite ceramic preform produced using the new injection molding tooling developed under Task 3. Figure 2 is a microscope image of the piezocomposite, showing the PZT ceramic pillars surrounded by inert matrix material.

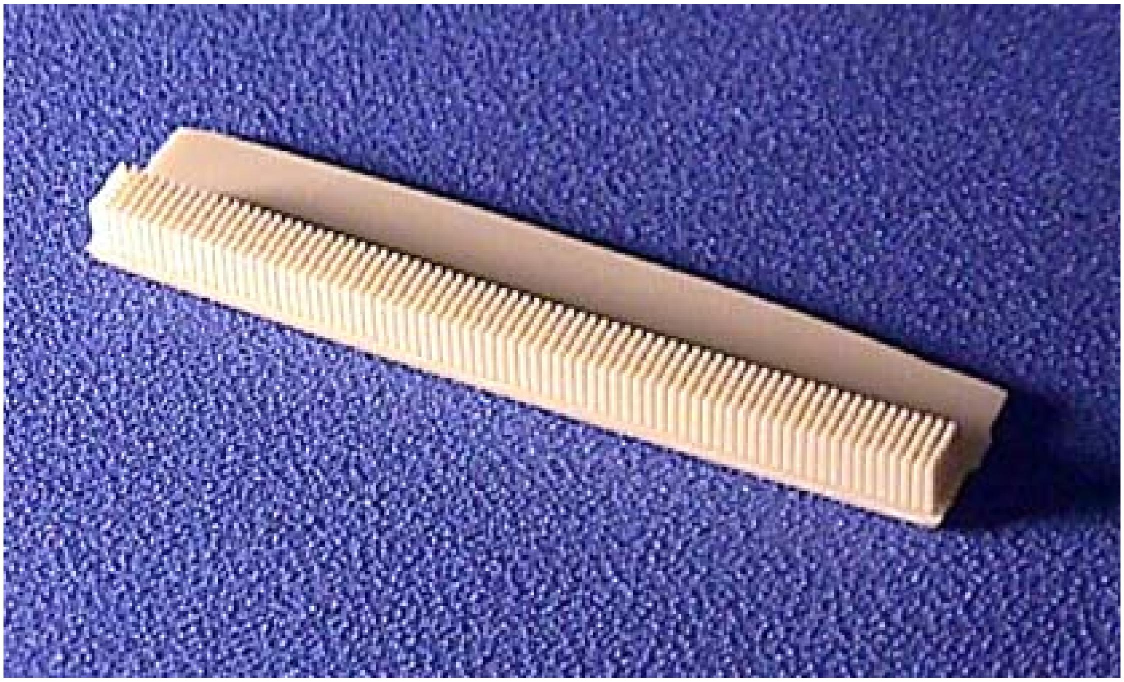

Figure 1. A piezocomposite ceramic preform produced with the new injection molding tooling. [The long dimension in this photo is about 50 mm.]

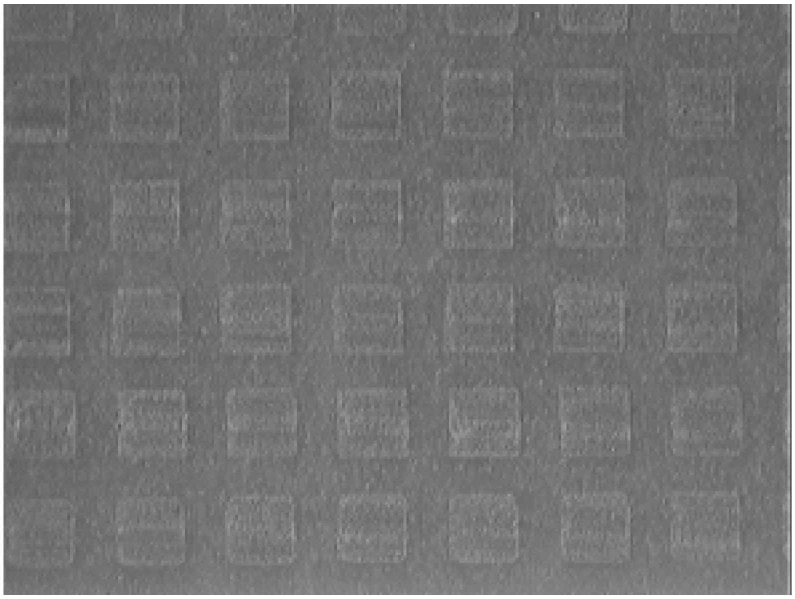

Figure 2. Microscope image of piezocomposite made from the ceramic preform shown in Figure 1. [The squares are the tops of the PZT ceramic pillars; in between is the polymer matrix material]

Figure 3 shows impedance and phase curves for three sample thicknesses. The impedance curves are clean, revealing an absence of interfering modes.

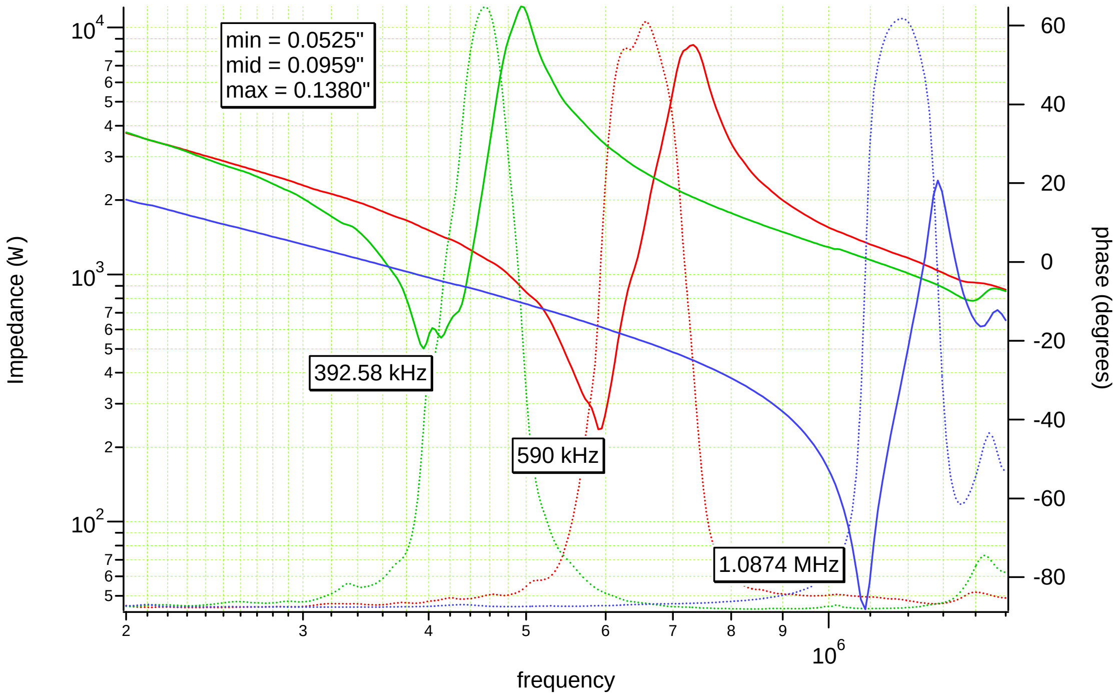

Figure 3. Impedance and phase vs. frequency for sample thicknesses of 1.33, 2.43, and 3.50 mm, showing clean resonant modes.

IMPACT/APPLICATIONS

The integration of a high performance, forward looking, low power sonar on AUV's involved in bathymetry, covert shallow water and surf zone mine detection and clearance operations will nearly double their operational effectiveness by providing a gap filler for the sidescan sonars. The forward looking array can also be used for obstacle avoidance and navigation, thereby improving the timeliness and efficiency of the survey methods currently employed.

TRANSITIONS

None

RELATED PROJECTS

None

PUBLICATIONS

1-3 Piezocomposite Arrays for Shallow Water AUV Applications, H. Pham, R. Stockhaus, S. Freed, B. Pazol, J. Cuschieri, L. LeBlanc, 2001 U.S. Navy Workshop on Acoustic Transduction Materials and Devices, Baltimore, MD, May 2001